UCRL- 99676
PREPRINT

An Instrument for Determining Spontaneous-Fission Properties of Millisecond Isotopes

R. J. Dougan
P. A. Baisden
E. K. Hulet

This paper was prepared for submittal to
Fifty Years With Nuclear Fission-
A Conference
Gaithersburg, MD, April 26-28, 1989

April 19, 1989

DISCLAIMER

AN INSTRUMENT FOR DETERMINING SPONTANEOUS-FISSION PROPERTIES OF MILLISECOND ISOTOPES

R. J. Dougan, P. A. Baisden, E. K. Hulet
Lawrence Livermore National Laboratory
808 East Ave
Livermore, Ca. 94551
(415) 422-8151

ABSTRACT

We have developed a spinning wheel analyzer of millisecond isotopes (SWAMI), an instrument to measure the kinetic energy of fission-fragment pairs from the spontaneous fission (SF) of millisecond isotopes. This instrument employs a continuous band of thin, aluminum foils mounted at the perimeter of a spinning wheel to stop and retain recoil products produced during continuous, heavy-ion bombardment of heavy, actinide targets. The rotation of the wheel moves the implanted reaction products past four pairs of surface-barrier detectors, where the energies of correlated fission fragments are measured. With this instrument, we can determine the mass and total kinetic energy (TKE) distributions for isotopes with half-lives between 0.5 and 300 ms. To date, we have used SWAMI to measure the mass and TKE distributions for two nuclides, 20-ms ^{260}[104] and 1.2-ms ^{258}No.

INTRODUCTION

The spontaneous and low excitation-energy fissions of actinide nuclides lighter than fermium exhibit systematic trends in their mass and TKE distributions. The mass distribution is asymmetric, with a heavy wing averaging about 140 amu and a light wing comprising the remainder of the mass. The TKE of the actinides increases linearly when plotted against the Coulomb parameter, $Z^2/A^{1/3}$, of the fissioning nuclide.[1] This behavior changes abruptly at ^{258}Fm, for which fission with a narrow, symmetric mass division and high TKE (235 MeV) becomes dominant.[2] These properties seem to be the result of the formation of two nearly spherical fragments, each with proton and neutron numbers close to that of the doubly magic ^{132}Sn nucleus.

The half-lives of transfermium nuclides are short, particularly those with even numbers of neutrons and protons. No even-even transfermium nuclides have been discovered with half-lives greater than 1 minute, and most have half-lives between 1 and 300 ms. To further investigate the transitions in SF properties of the heaviest nuclides, we have designed and used the SWAMI system at the 88-inch cyclotron at the Lawrence Berkeley Laboratory to measure the kinetic energies of fission-fragment pairs from the SF of isotopes with short half-lives (0.5 to 300 ms).[3] This has allowed us to determine the mass and TKE distribution of isotopes with millisecond half-lives. A schematic drawing of SWAMI is shown in Fig. 1.

EXPERIMENT

We produce the millisecond isotopes as compound-nucleus (CN) products formed by the bombardment of heavy actinide targets (^{249}Bk, ^{248}Cm) with heavy ions (^{15}N, ^{13}C). We use bombarding energies at the peaks of calculated excitation functions to optimize the yield of the desired CN recoil product. There is no elemental or mass identification of fissioning nuclei associated with the SWAMI apparatus.

Partial separation of the CN recoil products from nuclear transfer products and target knockover atoms is accomplished by taking advantage of their range and angular distribution. CN products have a narrow, forward-peaked angular distribution and a range characteristic of the full momentum provided by the formation reaction. The SWAMI system employs a collimator, located between the target and the collector foils, to restrict the angle of the emitted nuclear recoil products. CN products pass through the collimator, whereas transfer products emitted at larger angles are stopped. The energy of the reaction products is reduced by passage through thin metal foils covering the collimator. The thickness of these foils is chosen to degrade the energy of the CN products so that the end of their range occurs within the aluminum collection foil. About half of the CN products are stopped within the thin,

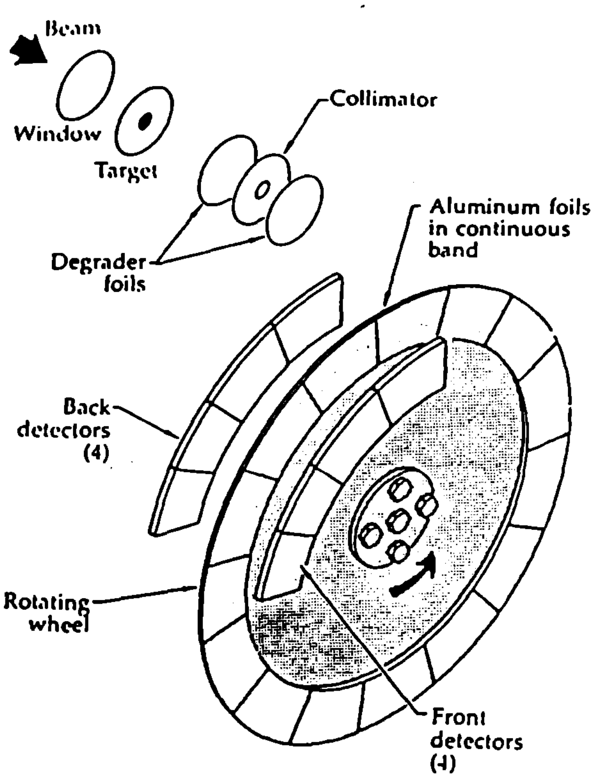

Figure 1. Schematic of the SWAMI instrument, used to measure coincident fragment energies from the spontaneous fission of millisecond nuclides produced by heavy-ion reactions with actinide-target isotopes. A portion of the recoil nuclei from the nuclear reaction is stopped in 100-μg/cm² aluminum foils surrounding the rotating wheel, where they are moved between opposing pairs of surface-barrier detectors.

rotating collector foils. Knockover products, with a very short range, are stopped and retained by the degrader foils. Transfer products, which usually have a range considerably greater than the CN products, largely pass through the collection foils, thereby allowing additional discrimination. We reduced the collection of transfer products by a factor of six through collimation and range discrimination.

The collector foils are mounted on the perimeter of a spinning wheel, which moves the implanted reaction products past four successive pairs of opposing surface-barrier (Si(Au)) detectors. We reduced the SF contribution from transfer products (^{256}Md/^{256}Fm) by an additional factor of 3-4 by replacing the collection foils with fresh ones every three hours. The energy of correlated fission fragments and a rough half-life are measured for the SF nuclides implanted in the collection foils. The overall efficiency with SWAMI for detection of fragment pairs from the millisecond isotopes was 5-6%. From each pair of fragment energies, the total-kinetic energy and fragment masses are calculated on the basis of conservation of mass and momentum.

The detectors require energy calibrations with an SF standard with well-characterized energy and mass distributions. We used specially prepared SF sources of ^{252}Cf for this purpose. Each source was prepared by volatilizing ^{252}Cf onto a 50-μg/cm^2 Al foil, supported on a trapezoidal frame of the same dimensions as was used for the collection foils. The Cf spot was then covered with another 57-μg/cm^2 Al by evaporation to give a Cf source close to the same total thickness as the collection foils, namely 100-μg/cm^2 Al. During calibrations, the standard was loaded on a collection wheel and then mounted in the SWAMI chamber. SF events were accumulated for both stationary and spinning-wheel conditions to determine the energy calibrations and pair-detection efficiencies. For calibrations, we used an average TKE of 181 MeV.[4]

RESULTS

We have determined the SF properties of two nuclides using the SWAMI system. The first, 20-ms ^{260}[104], has a broad TKE distribution, with a full width at half maximum (FWHM) of 45 MeV. The average TKE is 200.4 MeV. The mass distribution is symmetric and broad, with a FWHM of 36 amu. The second nuclide studied, 1.2-ms ^{258}No, again shows a broad TKE distribution; but for this nuclide, a skewing towards high TKE is observed. The average TKE is 206.5 MeV. The mass distribution for ^{258}No is symmetric, but with a decidedly narrower FWHM of 14.6 AMU.

With SWAMI, we have been able to measure the energy of fission fragments from the SF decay of millisecond isotopes. Collection on thin foils has resulted in good energy resolution, which is necessary to determine the TKE and mass distributions. The contribution of detected fragment pairs from transfer products, produced with much higher cross sections, has been effectively reduced. This was accomplished through range discrimination and collimation of the nuclear reaction products, as well as through frequent exchange of the collection foils.

This work was performed under the auspices of the U.S Department of Energy by Lawrence Livermore National Laboratory under contract W-7405-Eng-48.

1. V.E. VIOLA, K. KWIAKOWSKI, M. WALKER, "Systematics of Fission Fragment Total Kinetic Energy Release", Phys. Rev. C 31, 1550 (1985).

2. D.C. HOFFMAN et al., "12.3-min ^{256}Cf and 43-min ^{258}Md and Systematics of the Spontaneous Fission Properties of the Heavy Nuclides", Phys. Rev. C 21, 972 (1980).

3. R.J. DOUGAN, P.A. BAISDEN, E.K. HULET, "SWAMI: A New Instrument for Determining the Spontaneous Fission Properties of Millisecond Isotopes", submitted to Nucl. Instrum. Methods.

4. E. WEISSENBERGER et al., "Energy Calibration of Surface Barrier Detectors for Fission Fragments", Nucl. Instrum. Methods A 248, 506 (1986).